Experimental Trauma Surgery
Medical Faculty
Justus-Liebig University of Giessen (Germany)

2020 Proceedings of the 3rd International Conference on Trauma Surgery Technology in Giessen

17 October 2020
Hosted online due to Corona situation
Funded by the Deutsche Forschungsgemeinschaft

University Medical Faculty
Giessen (Germany)

Conference Organisation at JLU Giessen

M Ebeling, WA Bosbach, M Hofacker, KE Bosbach

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B Yu (McMaster University, Canada)
A Mieczakowski (University of Cambridge, UK)
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DFG grant BO 4961/4-1
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Correspondence
Wolfram A. Bosbach, PhD
Research Associate and Justus-Liebig Scholar
Experimental Trauma Surgery, Justus-Liebig University of Giessen
128, Aulweg
Giessen 35392
Germany
Email wolfram.bosbach@med.uni-giessen.de
Homepage https://www.uni-giessen.de/fbz/fb11/institute/klinik/chirurgie/uch/forschung/Wolfram

Preface

Dear Colleagues

Dear Speakers

Dear guests who logged in at zoom on 17 Oct

The **3rd** event of the **Giessen International Conference on Trauma Surgery Technology** on **October, the 17th 2020** was hosted on www.zoom.com in accordance with the worldwide corona situation. Dr Mieczakowski, Dr Yu, and Wolfram drafted in 2018 from Jan's apartment in Bremen the manuscript which was submitted to and **approved for funding by the Deutsche Forschungsgemeinschaft (DFG)**. At that time, we had no idea what substantial changes the conferencing concept would require. This is why we would like to thank again Michele. She first planned this year's event after the 2019 date and then in the spring of 2020 had to replan for the new situation.

The main topic for **2020** was **trauma surgery implants and their functionality**. The included figure (source: Dr Yu's introductory talk) shows some of the requirements for modern trauma implants. Resistance against wear and against the generation of debris particles, adapted fracture toughness and stiffness have to be considered to avoid implant failure. The three sessions this year specifically addressed these issues by 5 talks each. First, talks about **device functionality** were presented, followed by the second session on **surgical aspects of implants**, and the third which investigated optimised **surface properties**. As part of our ongoing collaboration, Bosco is overseeing our joint investigations about the mechanical stiffness in human femur head samples and the influence of osteoporosis thereon. Results are being prepared for publication at the moment.

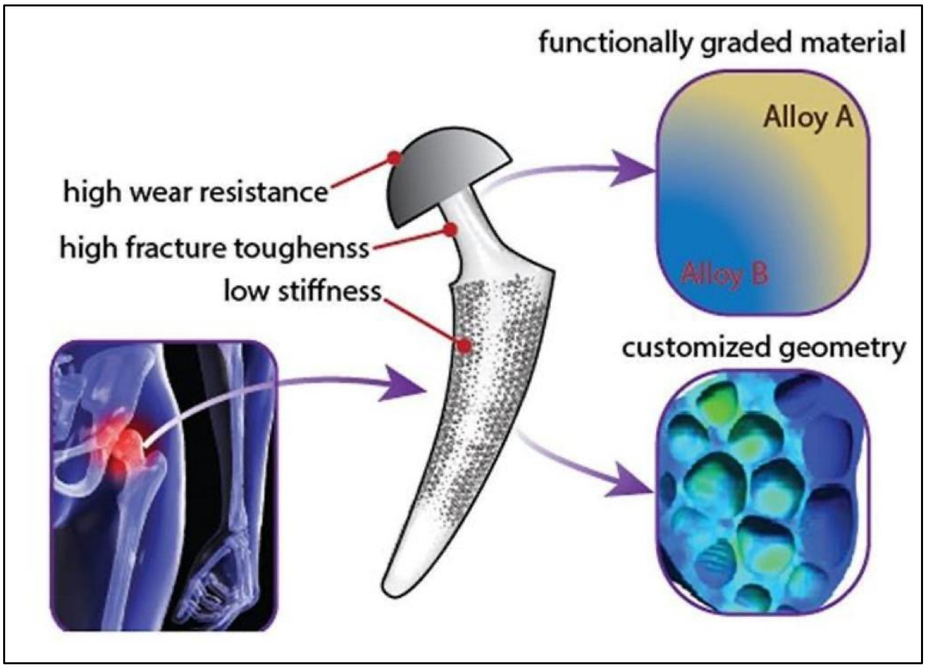

Figure: Sketch of a state-of-the art hip implant with highlighted functionalised sections: high resistance against wear in contact with acetabulum pelvis, high neck fracture toughness against traumatic implant failure, stem stiffness adapted to surrounding femoral bone tissue, achievable by graded alloys and by surface geometry designs (image source: Dr Yu's introductory talk).

Since the 2019 event, two more studies have been published by speakers where in both cases the Giessen event was able to make a contribution for discussion and exchange. The stimulation of an international **exchange of ideas and research results** has been the original reason for the DFG to fund our events. Joe's and Elisa's talks this year continue from those two studies and lead to the next steps of ongoing and future work. The 2020 event was again a platform for researchers and clinicians from different fields from different countries. Objective was again to stimulate **novel ideas for research work and follow-on funding proposals.**

We were positively surprised how well participants interacted in a virtual conference room and how many interesting discussions were started. We see this also as a chance for innovating our conferencing concept further and to use also in the post-corona future virtual formats.
The 3rd event attracted more participants from a greater number of countries than ever before. **Speakers this year came from North America, Europe, and the Far East**. At the time of the event's start on 17 Oct, local time for speakers ranged from

- 9 am in Ontario (Canada), to
- 3 pm in Frankfurt/Zurich, and
- 9 pm in Zhengzhou (China).

Amongst speakers, there were Giessen-regulars as well as Giessen-freshers.

The **closing talk** from Seper and Greg presented the first documented case of **osteosarcoma in a dinosaur** fibula. The dinosaurs did not innovate and eventually all died out as we know. **We as scientists** equally can get osteosarcoma and should see this probably as a wakeup call. We scientists enjoy structural conservatism so much in our habitats which we call research institutes. For us, there is equally a risk that we go extinct unless we continuously innovate and try new ways. We should not shy away from evolutionary competition and, au contraire, rather should embrace with eagerness the best, novel ideas.

Preparations for the 4th event have started. We will see how soon we meet again. We plan to have again a face-to-face component.

We shall see again, your scientific committee

Programme overview – adapted to 2020 Corona situation

Friday, 16 Oct 2020 - Cancelled due to Corona pandemic

~~*Evening get-together at the Giessen Old Brewery*~~

Day 1 - Saturday, 17 Oct 2020

- **Presentations with discussion rounds**

03.00 pm, Frankfurt time (CEST)

Log in via:

https://zoom.us/j/92883591118?pwd=UGJKTUdkLzN2WGpEWU5tUEI5Tm51UT09

Meeting-ID: 928 8359 1118

Password: gießen2020

Cancelled due to Corona pandemic

- ~~*Dinner party at the Giessen Boat House*~~

Day 2 - Sunday, 18 Oct 2020 - Cancelled due to Corona pandemic

- ~~*Interactive morning sessions:*~~
    - ~~*Osteosynthesis workshop (Dr Biehl)*~~
    - ~~*Visit to the University hospital's helipad*~~
    - ~~*Performance specifications in medical engineering (Dr Mieczakowski)*~~
- ~~*Lunch break*~~
- ~~*Departure by shuttle to Frankfurt airport*~~

Press statement (in German) by host institute Justus-Liebig University of Giessen

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Implantate in der Unfallchirurgie

JLU richtet Internationale Tagung zur Traumachirurgie in diesem Jahr online aus

Nr. 152 • 6. Oktober 2020

Implantate sind aus den Therapieverfahren der modernen Unfallchirurgie nicht mehr wegzudenken. Sowohl alltägliche Kreuzbandrisse beim Sport als auch die komplexe Polytraumaversorgung Schwerstverletzter nach Verkehrsunfällen erfordern auf den Patienten zugeschnittene, passgenaue Systeme. Das Potential für gesteigerten Patientennutzen bei weiter Optimierung heutiger Implantate ist am 17. Oktober 2020 das Thema der 3. Veranstaltung der seit 2018 jährlich in Gießen durchgeführten Internationalen Tagung zur Traumachirurgie.

Die englischsprachigen Vorträge werden dezentral online gehalten und sind dabei öffentlich zugänglich. Das diesjährige Online-Format ersetzt aufgrund der Coronabeschränkungen die normalerweise in Gießen real stattfinde Veranstaltung. Vortragende kommen aus Europa, Nordamerika und Fernost. Wie schon in den Vorjahren finanziert die Deutsche Forschungsgemeinschaft das Event.

- Weitere Informationen

https://www.uni-giessen.de/fbz/fb11/institute/klinik/chirurgie/uch/forschung/trauma-surgery-technology-conference-2020

- Termin

Samstag, 17. Oktober 2020, 15 Uhr
Zugangsdaten Online-Event:
https://zoom.us/j/92883591118?pwd=UGJKTUdkLzN2WGpEWU5tUEI5Tm51UT09
Meeting-ID: 928 8359 1118
Password: gießen2020

- Kontakt

Wolfram A. Bosbach, PhD
Experimentelle Unfallchirurgie

Presse, Kommunikation und Marketing • Justus-Liebig-Universität Gießen • Telefon: 0641 99-12041

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- **Spiegel der Forschung** - letztmalig 2013 erschienen
- **Imagebroschüre**
- **Booklet**
- **Gießener Universitätsblätter** der Gießener Hochschulgesellschaft e.V.

Web link: https://www.uni-giessen.de/ueber-uns/pressestelle/pm/pm152-20implantateinderunfallchirurgieonlinetagung (issued on 06 Oct 2020)

Detailed Programme with presented abstracts

Opening session – 03.00 pm, Frankfurt time (CEST)

- **Ebeling, Michele**
  Bosbach, Wolfram, University of Giessen
  Introduction about technical details and workshop structure
- **Group photo 2020 on zoom** (participation non mandatory)

Session 1 – Devices and device functionality, Chair: Bagherifard, Sara

- **Introductory talk:**
  Yu, Bosco, McMaster University
  Multifunctional Trauma Surgery Implants
- **Gonder, Nicole, Sarah, McMaster University**
  Development of Highly Tuneable Cellular Protective Bodywear using Rapid Prototyping and Additive Manufacturing
- **Mieczakowski, Anna, Ameliot Consulting, University of Cambridge**
  Investigation and Monitoring of Wound Microbes and their Bacterial Volatiles Through a New Sensor Technology
- **Deering, Joseph, McMaster University**
  Exploring design and surface modification strategies for porous metallic implants
- **Schwarz, Oliver, Fraunhofer IPA, Stuttgart**
  Learn from ants to build OP scissors

Session 2 – Surgery and bone, Chair: Heiss, Christian and Mieczakowski, Anna

- **Rier, Elyse, McMaster University**
  3D Point Cloud from CT Data to Assist Surgical Planning and 3D Printing
- **Aranguren van Egmond, Derek, University of Toronto**
  An investigation of the trabecular bone micro-architectures in osteoporotic human femoral heads using x-ray tomography
- **Schwarz, Oliver, Fraunhofer IPA, Stuttgart**
  Fish fins effect in anatomical forceps allows gentle gripping
- **Zheng, Kai, Zhengzhou University, Dalian Medical University**
  Medial Collateral Ligament Reconstruction Using Peroneus Longus Tendon Fixed by Interference Screw and Endobutton Fixation

- **Schwarz, Oliver, Fraunhofer IPA, Stuttgart**
  Extreme better usability of bone cutter after revision with biomimetic features

Session 3 – Tissue engineering scaffolds, Chair: Yu, Bosco

- **Mele, Elisa, University of Loughborough**
  Engineering materials for biomedical applications: from electrospinning to 3D printing
- **deVet, Taylor, McMaster University**
  Osteocyte electrical stimulation: Experimental design and culture media characterization
- **Senge, Jan Felix, University of Bremen**
  An approach towards novel roughness parameters for shot peened surfaces
- **Mora Sierra, Daniel Camilo, Politecnico di Milano**
  Numerical modelling of Ti6Al4V Additive manufactured lattice structures for bone implants

- **Closing talk:**
  Ekhtiari, Seper, McMaster University
  Osteosarcoma in a Dinosaur: A First-Time Diagnosis Confirmed through Comparison with a Human Specimen

Session 1 – Implants and functionality

Development of Highly Tuneable Cellular Protective Bodywear using Rapid Prototyping and Additive Manufacturing

Gonder Nicole Sarah, Tyedmers Walker Adam, Yu Bosco*

Department of Materials Science and Engineering, McMaster University, 1280 Main Street West, JHE 357, Hamilton, Ontario, Canada

* corresponding author, bosco.yu@mcmaster.ca

Developing tuneable cellular lattices using domain misorientations for tiling of 3-dimensional surfaces for impact absorption and traumatic brain injury mitigation in protective headwear (helmets).

Introduction Traditional protective bodywear tends to be made from homogenous materials with minimal tuneable structures. Through additive manufacturing, we can explore structures that were previously difficult to produce and study. Modern cycling helmets commonly contain solid expanded polystyrene (EPS) with a solid internal architecture, with internal linings such as MIPS and WaveCel [1].

Cycling impacts involving rotational forces to the head can lead to concussion, and other forms of traumatic brain injuries. Linings in bicycle helmets offer potential reductions in rotational acceleration to the head [1], whereas the rigid EPS internal architecture can be improved using cellular geometry for impact absorption, light weighting, and reusability after impact.

Through this study, we are exploring new type of protective wear to protect from forces that are commonly unaccounted for in impacts.

Method and materials Cellular structures to accommodate curvature will be developed through an iterative method to rapid prototype using additive manufacturing. We will compare these to existing architectures in modern cycling helmets, and those seen in cellular architecture in nature.

Results and discussion We are currently investigating cellular structures by mimicking biological structures, and applying existing algorithms developed by our previous study to our current work. We are exploring the usage of various CAD software allowing us to develop highly tuneable cellular structures that can be additively manufactured into free-form helmets for miniature testing. During this conference, we will summarize the results of our work-in-progress.

Conclusions and future work Presently, we have developed numerous geometries and are beginning the testing phase using additive manufacturing with promising results from initial simulations. For this study, we have narrowed down our study to cycling helmets, but plan to expand to design other type of protective body wear on this in future studies (see example in reference [2]).

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Conflict of interest

The authors declare that there are no conflicts of interest.

Funding sources

The Deutsche Forschungsgemeinschaft (DFG, grant No BO 4961/6) provided support for the conference at Giessen.

Investigation and Monitoring of Wound Microbes and their Bacterial Volatiles through a New Sensor Technology

Mieczakowski Anna

Director at Ameliot Consulting

Industrial Fellow at the Engineering Design Centre, University of Cambridge

Correspondence: anna@ameliot.com

Introduction Seven different species of microbes tend to be present in most wound infections, emitting volatile compounds through skin secretions, including predominately acetone, CO2, ammonia and amine:

1. Staphylococcus aureus – embedded closer to the wound surface;
2. Pseudomonas aeruginosa – embedded deeper within the wound bed;
3. Candida;
4. Enterococcus;
5. Aeromonas;
6. Micrococcus;
7. E. coli.

These bacterial volatiles can be detected from the wound dressing material, as well as directly from the wound's bed. However, detection of these species of bacteria usually requires sample and laboratory testing which is costly, inconvenient and time-consuming in the current medical practices for both patients and outpatients.

While 76 million of people worldwide suffer from acute and chronic wounds annually due to accidents, complications from diabetes, obesity and cardiovascular disease, currently medical practitioners (predominantly nurses) evaluate wound-status through a visual inspection based on experience (not on data), routinely changing dressings every 2 days, which in more severe cases requires anaesthetic and costly theatre time. 30% of wounds lack an accurate diagnosis due to treatment by non-specialist clinicians and 85% of dressings are changed too early, hampering healing [1]. Thus, a wound dressing equipped with a point-of-care, real-time sensor could significantly optimise and improve wound management and therapy.

Method and materials Together with a number of sensor development companies, an academic institution and a Hospitals Foundation Trust based in the UK, the author is involved in a project developing a new sensor technology for detecting in real-time the bacterial volatiles from the above-mentioned seven different genera of microbes in order to minimise infections by continually monitoring changes to the wound's bed and modifying treatment when any changes occur. Early diagnosis and management of wound infection is essential to avoid complications and this project offers a non-invasive method for diagnosing wound condition in real-time among both patients and outpatients, thus enabling appropriate treatment and reducing the risk of further complications. The project also aims to contribute to cost-effectiveness and improve the quality of life of the affected patients.

Ongoing work Despite that this work is currently underway, it already demonstrates the significant potential of the sensor technology for improving the quality of life for both patients and outpatients, given that, for example in the UK, 55% of outpatient cases are not being followed up and the outpatients' wounds being only seen when there is another medical problem. The sensor has a major potential to improve the time, pain management, speed and cost during healing of acute and chronic wounds, lowering the number of deaths as a result of undetected infections, antibiotics overuse, amputations, anaesthetic and theatre-use costs, by improving patient care in the hospital and the community, as well as speeding up clinicians' reactions to the imbalances in the wounds' bacterial volatiles' levels. Another benefit is that the sensor is planned to be inexpensive (£5-10 per use) to apply in dressings and the aim is to also provide it for use in non-clinical settings.

Bibliography

[1] Guest, J. F. et al. (2015) "Health economic burden that wounds impose on the National Health Service in the UK". BMJ Open Journal.

Disclosure The author is owner of the consulting business Ameliot which is part of a consortium of organisations developing this sensor technology.

Funding sources Financial support by Ameliot Consulting was provided. The Deutsche Forschungsgemeinschaft (DFG, grant No BO 4961/6) provided support for the conference at Giessen.

Exploring design and surface modification strategies for porous metallic implants

Deering Joseph[1]*, D'Elia Andrew[1], Clifford Amanda[1,2], Zhitomirsky Igor[1,3], Grandfield Kathryn[1,3]

[1] *Department of Materials Science and Engineering, McMaster University, Hamilton, Canada*

[2] *Leslie Dan Faculty of Pharmacy, University of Toronto, Toronto, Canada*

[3] *School of Biomedical Engineering, McMaster University, Hamilton, Canada*

* corresponding author, deeringj@mcmaster.ca

This work investigates the design and application of coating technologies to influence osseointegration on the interior of porous metals built by additive manufacturing. A polymethylmethacrylate composite coating infiltrated the interior of a porous scaffold to increase Saos-2 cell metabolism, and early trials with solvent cast alginate show promise.

Introduction Recent developments in metal additive manufacturing processes have enabled the fabrication of complex implant geometries for orthopaedic and prosthodontic applications. In particular, the design of porous materials offers an innovative approach to improve functional bone-implant anchorage at a defect site [1] and mitigate bone resorption that may arise from stress-shielding [2]. During early-stage osseointegration, bone apposition occurs mostly in the outer layers of the porous material, with only minimal nucleation in the scaffold interior [3]. Surface modification strategies are needed to homogenize bone apposition throughout the scaffold and lead to improved implant stability.

Method and materials Scaffolds were designed in Autodesk Netfabb and fabricated from 304L stainless steel powder using selective laser melting (Figure 1) [4].

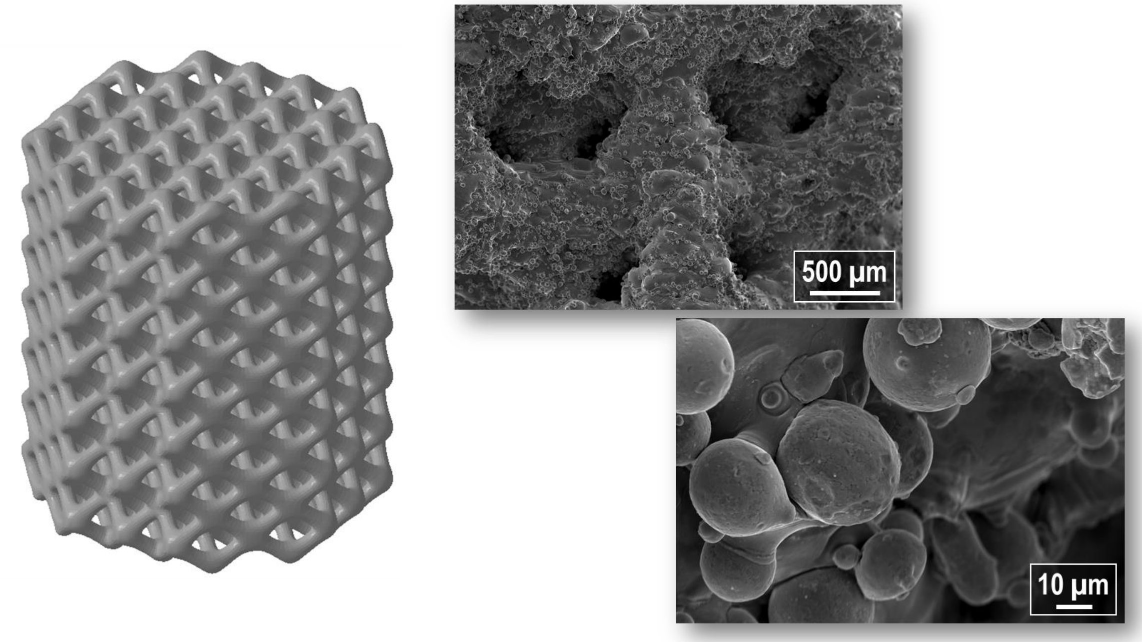

Figure 1: Porous scaffold design and micrographs showing surface topography and pore morphology of the scaffold

Polymethylmethacylate (PMMA) films with added alumina nanoparticles were deposited onto the scaffold by dip coating and subsequent solvent evaporation. Coating coverage was assessed by energy dispersive X-ray spectroscopy of the cross-section. Metabolic assays were used to assess Saos-2 cell viability and proliferation on solid cylinders, porous cylinders, and PMMA-composite coated porous cylinders. Early work on biomolecule functionalization by alginate solvent casting has also been conducted.

Results and discussion Scanning electron microscopy confirmed deposition of the PMMA-composite coating on the scaffold interior. Distinct alumina particles were visible in the PMMA films on both the exterior of the scaffold and, as shown in Figure 2, around the periphery of interior struts in the scaffold. Energy dispersive X-ray spectroscopy showed that films deposited on struts have a higher intensity of alumina and carbon than the remainder of the sectioned midplane, which is rich in elements characteristic of the stainless steel scaffold (iron, chromium, nickel, etc.) [5]. The alumina nanoparticles add topography at a smaller length scale than residual surface particles from selective laser melting. In vitro assays with osteoblast-like cells proved that the composite-coated porous scaffolds promoted significantly higher cellular metabolism compared to solid stainless steel cylinders after seven days of culture [5].

Conclusions and future work Coatings serve as an effective means to modify the interior of porous metallic implant structures for osteogenic applications. These coating technologies can be used for targeted delivery of bioactive agents or other functionalized biomolecules to the scaffold interior. Future work will focus on modifying coatings to integrate sustained protein release and induction of therapeutic pseudohypoxia on the scaffold interior to improve osseointegration.

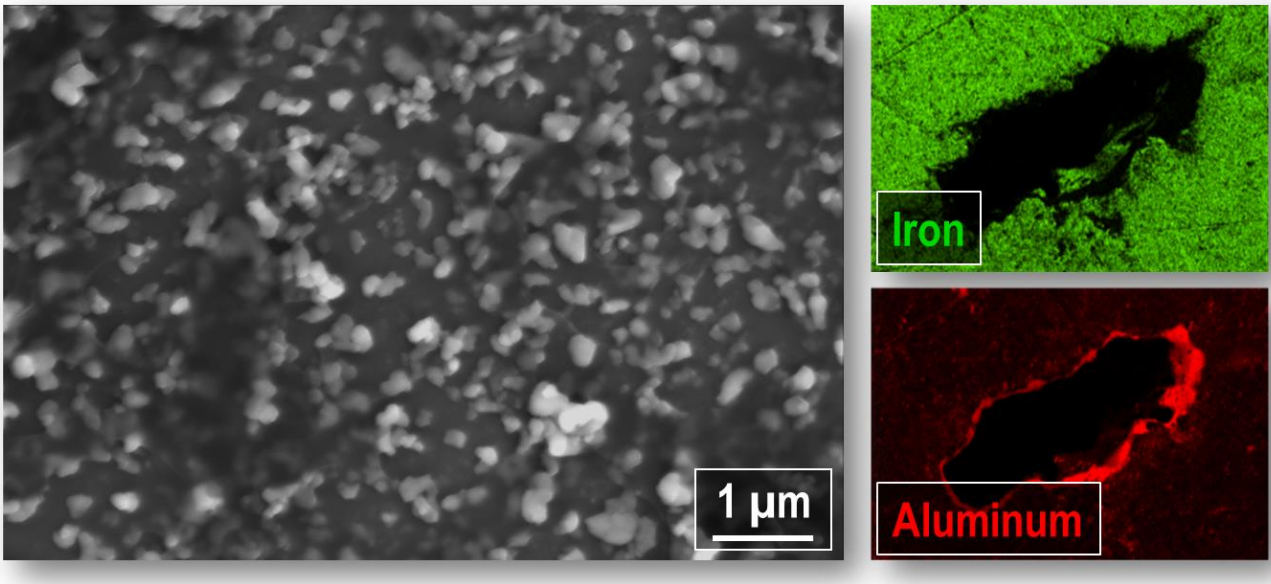

Figure 2: Micrographs of PMMA-alumina composite coating on the interior of a porous metallic scaffold. Characterstic X-rays for coating components are more intense around pore periphery.

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Conflict of interest

The authors declare that there are no conflicts of interest.

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Learn from ants to build OP scissors

Oliver Schwarz[1], Simon Schuck[1], Jonas Schiebl[1], Franz Brümmer[2]

[1] *Fraunhofer Institute for Manufactoring Engineering and Automation IPA,*

[2] *Universität Stuttgart, Germany*

* corresponding author: oliver.schwarz@ipa.fraunhofer.de

In endoscopic operations in human surgery, precision and efficiency combined with high reliability are crucial. Scientific progress in this field is largely determined by the development of new instruments and depends on their development. In the course of this progress, fungus breeding ants and their special way of cutting leaves will serve as a biomimetic example.

Leaf-cutting ants are the most successful of their kind, which is not the last of other effective, efficient and precise leaf-cutting techniques. The filigree cuts of these ants allow them to make an arc in a field that is also filigree. In human surgery, and especially in minimally invasive procedures, precision and efficiency combined with high reliability are very important.

The asynchronous cutting of the ant is a special aspect of this technique. The two lower jaws thus fulfil completely different tasks. Remarkable here is the method of simultaneous knife and scissors cutting, which combines the advantages of both techniques. This special feature was taken up and adapted. The result is scissors that could cut more effectively, especially where little force can be applied due to the small size (neurosurgery) or where endoscopically compact tissue has to be removed.

Conflict of interest

The authors declare that there are no conflicts of interest.

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Session 2 – Surgery and bone

3D Point Cloud from CT Data to Assist Surgical Planning and 3D Printing

Rier Elyse[1], Wohl Gregory[1,2]

[1] *McMaster School of Biomedical Engineering, McMaster University, Hamilton, Ontario, Canada*

[2] *Department of Mechanical Engineering, McMaster University, Hamilton, Ontario, Canada*

* corresponding author, riere@mcmaster.ca

The overall goal of our work is to develop a platform that allows users to easily visualize and manipulate CT data with the intent to facilitate surgical planning and potential rapid prototyping of biomedical implants.

Introduction: Surgeons can visualize the anatomy of defects by processing computed tomography (CT) data using software such as MIMICS (Materialise) to create 3D models of the area of interest [1]. These models can aid in preoperative planning and design of implants [1]. Although software tools are available to create 3D models or STL files, they can be expensive or require technical expertise. The overall purpose of this project is to create an independent software platform that would allow surgeons to manipulate segments of a CT scan and enable generation of STL files for surgical planning or additive manufacturing.

Method and materials: An anonymized CT data set of DICOM images of a skull (Discovery CT7, helical mode, GE Medical Systems) were used to develop the tool. The algorithm to extract a 3D point from CT data was first developed in MATLAB and then ported to Python. Image files were uploaded into MATLAB and Python and converted from grayscale to Hounsfield Unit (HU) using rescale slope and rescale intercept from the DICOM header. Images were binarized to isolate bone from surrounding tissue (threshold = 350 HU) based on [2]. Binarized images were subjected to a Canny edge detector to identify surfaces of the skull. Points were converted into spatial coordinates to create a point cloud. In-plane spatial coordinates (x,y) were obtained based on the edge location in each slice and pixel spacing of the CT images. Longitudinal coordinates (z) were summation of spacing between slices and the slice thickness for each slice.

Results and discussion: From visual inspection, the shape and the curvature of the surface of the skull was maintained in both point clouds. Dimensions of the point clouds obtained are summarized in Table 1. The variation between the number of points and the dimensions of the point clouds was likely caused by the variations in the Canny edge detector functions used in the two platforms. These dimensions are reasonable for an adult human skull considering that the CT images used did not contain a portion of the skull. The point clouds were both successfully saved as matrices containing the surface points representing the skull. This representation reduces the size of the data from a stack of DICOM files to a simple Nx3 matrix of doubles where N is the number of points in the point cloud.

Conclusions and future work: In next steps, the current algorithm will be modified to be compatible with data files for CT machines from other manufacturers. The 3D point cloud will be sampled based on curvature to reduce the size and will be converted into a 3D STL model. This model will act as the base for a program which will provide users a method to manipulate and extract 3D portions of the skull to create patient-specific implantable devices.

Table 1: Dimensions of obtained point clouds

	Number of Points	Height (z) [mm]	Length (x) [mm]	Width (y) [mm]
Matlab	307,250	238	139	152
Python	282,938	238	140	152

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Conflict of interest

The authors declare that there are no conflicts of interest.

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An investigation of the trabecular bone micro-architectures in osteoporotic human femoral heads using x-ray tomography

Aranguren van Egmond Derek[1], Biehl Christoph[2,3], Kampschulte Marian[4]; Heiss Christian[2,3], Bosbach Wolfram A[2,3], Yu Bosco[5]*

[1]*Department of Materials Science and Engineering, University of Toronto, 184 College Street, M5S 3E4, Toronto, Ontario, Canada*

[2]*Department of Trauma, Hand and Reconstructive Surgery, University Hospital of Giessen, Germany*

[3]*Experimental Trauma Surgery, Justus Liebig University of Giessen, Germany*

[4]*Departmenf of Diagnostic, Interventional, and Paediatric Radiology, University Hospital of Giessen, Germany*

[5]*Department of Materials Science and Engineering, McMaster University, 1280 Main Street West, JHE 357, Hamilton, Ontario, Canada*

* corresponding author, bosco.yu@mcmaster.ca

An image analysis method has been developed to investigate micro-CT scans of the trabecular bone micro-architectures in human femur heads. Preliminary results show that the spatial distribution of pore structures within human trabecular bone is similar to stochastic pore arrangements observed in animal bones, plant cells, and other porous materials found in nature. They also suggest that the degree of randomness in the structures is not correlated to the degree of bone loss and mechanical resilience of the femoral neck. However, prior observations have demonstrate that porosity, trabecular morphology, and the fracture toughness of bone are indeed all correlated. More investigation is needed to provide a conclusive statement.

Introduction and scope of study Cellular structures are a type of micro-architecture that is ubiquitous in nature. They can be found in plant cells (e.g. bamboo, wood), as well as the trabecular bones of animals (e.g. bird bones, femoral heads in mammals) [1]. Cellular structures have superior stiffness-to-weight and strength-to-weight ratios compared to their solid (fully dense) counterparts. For this reason, engineers have long mimicked nature in developing human-made cellular solids (also known as lattice materials) for use in structural applications. However, the current scientific understanding of mechanical behaviour (especially fracture mechanics) in cellular structures has been more focused on periodic (identical tessellations of a single cell shape) cellular structures, as opposed to the stochastic (or "random") structures found in nature [2-3].

The goal of the current study is to gain insight about the spatial distribution of trabeculae and how their randomness might relate to mechanics, especially in the case of femoral neck fracture in the hip bones of human patients that are suffering from osteoporosis.

Method and materials

The first two authors of the current proceeding (D. Aranguren van Egmond and B. Yu) have previously developed a forthcoming image analysis method to examine the micro-architectures of engineered and natural cellular solids in a quantitative way. In this study, we will adapt this quantitative method to analyse the micro-CT scans of the trabecular bone structure in multiple specimens of osteoporotic human femoral heads. The results from this study will then be compared with other cellular structures observed in nature. For that purpose, femur head samples were scanned by micro-CT. Image post-processing followed.

Results and discussion Based on preliminary analysis of the CT scans, the relative porosity of the femur head was clearly observed to increase with greater proximity to the fracture site. This suggests that osteoporosis, bone porosity, and the fracture toughness of bone are all correlated, in line with traditional bone density analyses.

There did not appear to be a significant change in the metric of microstructural “randomness” of the trabecular bone relative to the measurement location’s distance from the fracture site. It was observed that the degree of randomness of trabecular structures is in agreement with other typical cellular structures found in nature. This agreement suggests some degree of preferential intent in the distribution of pores as originally documented in Wolff’s law already in 1892 [4].

Conclusions and future work Our preliminary results in the current investigation confirm that bone porosity can be a major governing factor of the fracture toughness of trabecular bone, leading to a greater likelihood of bone fracture. Meanwhile, the effect of microstructural “randomness” remains inconclusive. There remain several challenges ahead in this form of quantitative image analysis. First, a representative sample set (potentially multi-centre) needs to confirm the above findings. Second, bone samples are not free from mechanical damages during surgical procedures. Overcoming these challenges will provide useful new insights and indicators as to why, and perhaps how, femoral neck fracture occurs, further elucidating the influencing mechanism of osteoporosis.

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The authors declare that there are no conflicts of interest.

Ethics approval

Ethics approval from Giessen University Medical Faculty, christoph.biehl@chiru.med.uni-giessen.de

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Fish fins effect in anatomical forceps allows gentle gripping

Oliver Schwarz*, Lucia Kölle

Fraunhofer Institute for Manufactoring Engineering and Automation IPA, Department Biomechatronic Systems, Germany

* corresponding author: oliver.schwarz@ipa.fraunhofer.de

Objects sometimes get damaged by anatomical forceps or slip out of their grip. Therefore, a forceps based on the Fish fins effect was developed. This effect was discovered 20 years ago when fishing and was used in biomimetic robot grippers from Festo. The jaws of the forceps adapt to the shape of the object that is handled with it while standard anatomical forceps force objects to adapt to their shape. Due to this unique property, less and more uniform pressure is applied on the object. Furthermore, it is possible to apply targeted pressure on objects by using the tips of the Fish fins effect -forceps. This offers the usual properties that users expect from forceps. Soft tissues can be handled with these forceps as well. This biomimetic instrument was chosen In the Devicemed magazine, in the "Research" section, foreceps were ranked second among the best developments in Medical technology selected in 2018.

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Medial Collateral Ligament Reconstruction Using Peroneus Longus Tendon Fixed by Interference Screw and Endobutton Fixation

Zheng Kai[1,2], Yang Liang[2]*, Zou Zaijun[2], Su Yuliang[2] , Zheng Liang[2], Meng Fanshuai[1]

[1]*Zhengzhou Central Hospital affiliated to Zhengzhou University*

[2]*The Second Affiliated Hospital of Dalian Medical University*

* corresponding author: yangliangyang@126.com

Introduction To perform an evaluation of clinical effects in medial collateral ligament (MCL) reconstruction using peroneus longus tendon fixed by interference screw and an Endobutton fixation device.

Planned methods We plan to select suitable patients to be treated with MCL reconstruction by our method. We are going to quantify knee joint biomechanics as follows: by the Lysholm knee score, the IKDC score, the range of motion, the distance of medial knee space in 0° and 30° stress x-rays, the difference of distance between medial and lateral knee space in 0 ° and 30° stress x-rays, and by gait analysis at the last follow-up.

Expected Results and Outlook We expect that in medial side which will be treated by surgical intervention the data will differ significantly comparing status preoperatively and postoperatively. Our operation method would gain tendon easily and could provide perfect medial stability of the knee, fewer complications. These long-term assessments would need further follow-up.

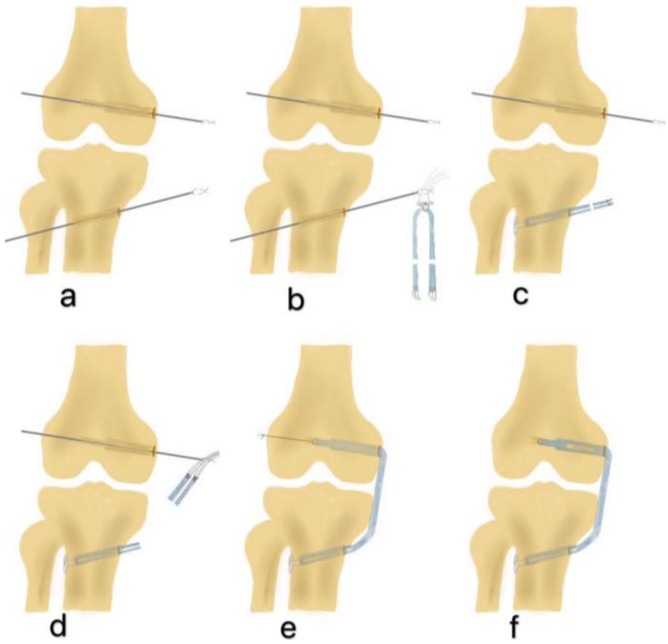

Figure:
a.Femoral canal 4.5mm,medial bone canal 7mm,tibial canal 4.5mm;

b.Endobutton with tendon through the tibial canal;

c.Turn over and fix Endobutton on the bone;

d.Guide the tendon;

e.Tendon cross the femoral canal;

f.Interference screw fix on the femoral.

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Extreme better usability of bone cutter after revision with biomimetic features

Oliver Schwarz*, Miroslav Miklosovic

Fraunhofer Institute for Manufactoring Engineering and Automation IPA, Department Biomechatronic Systems, Germany

* corresponding author: oliver.schwarz@ipa.fraunhofer.de

A "swallowing" bone punch modelled on the dentition of the snake Anaconda was developed, which sterilely holds the resectate inside the instrument after the forceps have been closed. The next bone piece can be resected immediately. The resectates are in the cartridge in the order in which they were removed and can be used for biopsies or removed and implanted again at the end of the operation. The punch or cartridge can hold 40 resectates, which means that the punch can remain in the operated area for a long time without being emptied constantly. The cutting mechanism has been modified from the carnivorous dentition of the feline (Feliformia). This saves approx. 50% of the force required for cutting and the cuts have clean cutting edges in contrast to the traditional punch cutting mechanism. It could be shown that biomimetics enables an effective transfer into medical technology.

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Session 3 – Tissue engineering scaffolds

Engineering materials for biomedical applications: from electrospinning to 3D printing

Mele Elisa

Materials Department, Loughborough University, LE11 3TU, Loughborough (United Kingdom)

Correspondence: e.mele2@lboro.ac.uk

One of the main requirements that scaffolds for tissue engineering should possess is a porous structure with interconnected porosity that promotes cells and nutrients infiltration, and yet has mechanical strength to support *in vivo* loading. Three main approaches have been proposed so far to achieve this goal: manufacture natural or synthetic biomaterials, decellularise tissues and stimulate cells to generate their own matrix. My research focuses on the first approach and this seminar is an overview of the technologies currently used in my group to manufacture biomaterials with multiscale porosity [1-4]: electrospinning, phase separation and 3D printing. The resulting scaffolds possess a hierarchical structure where layers of nanofibres act as a biomimetic interface for cell attachment and proliferation, while porous 3D structures provide mechanical support.

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Osteocyte electrical stimulation: Experimental design and culture media characterization

deVet Taylor[1,3]*, Bashar Roshan[2], deBruin Hubert[1,3], Wohl Gregory R.[1,2]

[1] *McMaster School of Biomedical Engineering*

[2] *Department of Mechanical Engineering, McMaster University*

[3] *Department of Electrical and Computer Engineering, McMaster University*

* corresponding author: devett@mcmaster.ca

Introduction Osteocyte lineage and morphology are well understood, but their behaviour within the tissue is widely debated [1]. The accepted hypothesis is that osteocytes can sense mechanical strain within the bone matrix and control the response of osteoblasts and osteoclasts accordingly [1]. Research indicates that the bone matrix experiences changes in electrical charge when stressed through streaming potentials in the canaliculi and piezoelectricity of the collagen-hydroxyapatite junctions [2], [3]. The application of external electrical stimulation (ES) has been shown to increase bone formation which indicates that the cells are electrically sensitive [3]–[5]. This is currently under-researched for osteocytes, which are presumed to be the ones sensing the stimulus. The goal of our work is to develop an experimental platform to further our understanding of how osteocytes respond to electrical stimulation.

Method and materials To apply ES to osteocytes in vitro we have been developing a device to fit into 12 and 24-well cell culture plates. To avoid electrode-electrolyte interactions, we use platinum electrodes for their inert properties. These electrodes were placed in each culture well, parallel to each other, suspended above the bottom of the well. When cells are introduced, they will not have anything impeding their ability to move and grow. A DC stimulus was applied with magnitudes between 100 and 800 µAmps using a constant current supply. The resistance of two media types, Dulbecco's modified eagles medium and McCoy's medium, were monitored over time to track their electrical response behaviour.

Results and discussion ES of culture media caused visible changes in the media, as well as electrical properties over time. The resistance of the media increases rapidly upon application of the electrical stimulus and plateaus between 60 and 120 minutes of stimulation. The pH of the media also changes, with the media around the cathode becoming basic and media at the anode, acidic. This pH gradient disperses over time, corresponding to the resistance plateau. The resistance of the media is directly linked to the amount of current going through the media, with the relationship following a power curve. No relationship between voltage and current or voltage and resistance was found for the media.

Conclusions and future work These experiments have shown us which conditions allow for more stable behaviour of the cell culture media with the application of ES. This should give us more insight into whether outcomes from ES cells are coming from the stimulation or the electrochemical reactions that are present in the media due to the ES. This will be a first step into generating a controlled ES environment for bone cells in culture.

The future of this work may also include the introduction of a set of measuring electrodes in each well to see how much stimulation is reaching the cells at the bottom of each well. This information will allow us to strengthen conclusions on what aspect of the stimulation is causing behaviour in the cells.

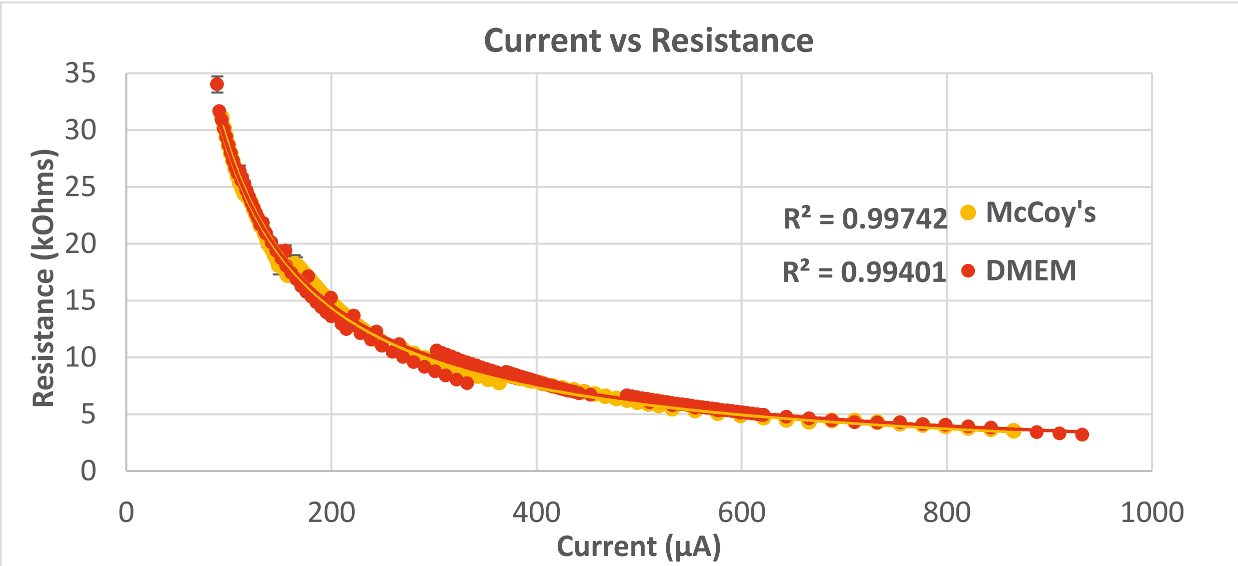

Figure: Current vs Resistance trend of DMEM and McCoy's Cell Culture Media

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An approach towards novel roughness parameters for shot peened surfaces

Senge Jan Felix[1]*, Bagherifard Sara[2], Bosbach Wolfram A[3], Dlotko Pawel [4]

[1] *ALTA Institute, Department of Mathematics & Computer Science, University of Bremen (Germany)*

[2] *Department of Mechanical Engineering, Politecnico di Milano (Italy)*

[3] *Faculty of Medicine, Experimental Trauma Surgery Justus Liebig University of Giessen (Germany)*

[4] *Dioscuri Centre in TDA, Mathematical Institute, Polish Academiy of Science*

* corresponding author, janfsenge@uni-bremen.de

Surface topography and roughness evaluation plays an important role in many problems such as friction, contact deformation or coat adhesion. To get a better understanding of the real surface geometry several, different parameters need to be considered resulting in a reason for different parameters for surface roughness evaluation [1]. In particular, the geometry is so complicated that finding new evaluations is still of interest.

Roughness parameters are either calculated based on a profile (two-dimensional) or a surface (three-dimensional) obtained via, for example, electronic contact profilometry. While profile roughness parameters are still more common, surface roughness parameters can yield more significant results. The most prominent parameters for characterizing the topography are amplitude parameters like the arimthmetic average height/deviation R_a, the ten-point height R_z, kurtosis R_{ku} and skewness R_{sk} [2].

Shot peening is a surface treatment used to mainly enhance the resistance of certain metallic components by striking a surface with high-velocity shots resulting in plastic deformation inducing a residual compressive stress layer. To help understand the changes of the surface area roughness during and after shot peening depending on peening parameters such as velocity and shot size, it is helpful to use numerical simulation [3] as well as considering other roughness parameters - possibly incorporating the evolution of this process and the spatial information.

Topological data analysis (TDA) is a field of computational topology concerned with observing topological structure of data using topological and geometric [4]. A prominent method is persistence homology which is used to compute topological features of a given space at different scales [5]. By considering a sequence of sublevel sets using the height function of the surface area, one obtains a filtration for which we can track the changes of the topological information. Features are characterized by the time at which they occur and for how long they persist. A summary of these features and thus a descriptor of the surface is the persistent diagram. This particular approach captures not only the amplitude information but incorporates the spatial information as well.

Incorporating a persistence-based parameter proves helpful in distinguishing different shot peened surfaces in comparison to the standard roughness parameters. Furthermore, this can be extended into several directions as a different function for creating the filtration results in a different characteristic of the persistence-based descriptor. Some of these are discussed in the presentation.

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Numerical modelling of Ti6Al4V additive manufactured lattice structures for bone implants

Mora Sierra, Daniel Camilo, Heydari Astaraee, Asghar, Guagliano, Mario, Bagherifard, Sara*
Department of Mechanical Engineering, Politecnico di Milano, Milan, Italy
* corresponding author, sara.bagherifard@polimi.it

In this study, a numerical model is developed and validated for the prediction of deformation and mechanical properties of lattice structures. Most promising ones are identified by comparing the mechanical properties to those of human bone tissue.

Introduction A significant requirement for a bone implant is to mimic the stiffness of host bony tissue since the mismatch creates stress shielding in implanted bones, which is one of the root causes of the reduced lifespan of commercial bone implants. In this work continuous functionally graded porous scaffolds (FGPSs) made of Titanium alloy Ti–6Al–4V are studied. The structures are based on different unit-cell topologies at different overall porosities. Lattice structures' topology is modulated by means of different gradient strategies to be mechanically compatible with surrounding bones, while offering an adequate mechanical resistance.

Method and materials A numerical model was developed in Abaqus by Dassault Systems in order to study the mechanical behavior and deformation mechanisms of the above-mentioned porous structures. CAD models of the structures were developed using Autodesk Inventor Professional and then imported into the FE software. An elastic plastic model was implemented to simulate the failure of the additively manufactured scaffolds under compression. Analytical rigid shells with were created to replicate the upper and lower compression plates of a testing machine.

Results and discussion The model was validated by means of experimental data provided in the literature. Stress–strain curves were extracted from simulations' results, and elastic modulus, yield strength, and peak stress were estimated according to standards. Estimated mechanical properties are compared to those of human bone in order to underline the most promising structures. Mechanical properties of structures based on pillar octahedral unit cell were found to be, for a specific porosity, lower than corresponding structures based on cubic unit cell. Only the elastic modulus of pillar octahedral structures having 85% porosity were close to the upper limit found on the literature for trabecular bone. On the other hand, remaining structures for both pillar octahedral and cubic unit-cell-based structures had elastic modulus within the range of cortical bone. The main advantage seen with FGPSs compared to uniform structures is that although elastic modulus remains similar for specific porosities, the other mechanical properties are still high enough to ensure mechanical integrity of the structures.

Conclusions and future work The numerical model developed provides an important tools to design open porous lattice structures. The results obtained provide a solid background to further more inclusive and accurate numerical models. The next step is to experimentally study the structures analysed here to understand in more detail the accuracy and possible improvements of the current model.

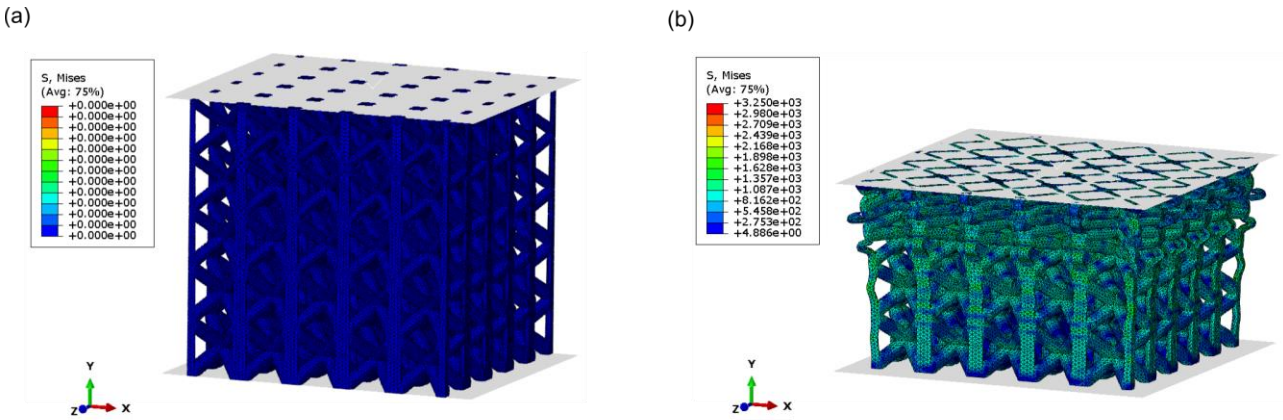

Figure 3: Stress distribution on a FGPS (a) prior and (b) after compression.

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Closing talk

Osteosarcoma in a Dinosaur: A First-Time Diagnosis Confirmed through Comparison with a Human Specimen

Seper Ekhtiari[1]*, Kentaro Chiba[2], Snezana Popovic[3], Rhianne Crowther[4], Gregory Wohl[5], Andy Kin On Wong[6], Darren H. Tanke[7], Danielle M. Dufault[8], Olivia D. Geen[3], Naveen Parasu[9], Mark A. Crowther[3], David C. Evans[8]

[1] *Division of Orthopaedic Surgery, Department of Surgery, McMaster University, Hamilton, Canada*

[2] *Department of Biosphere-Geosphere Science, Okayama University of Science, Okayama, Japan*

[3] *Department of Medicine, McMaster University, Hamilton, ON, Canada*

[4] *Department of Biology, Trent University, Peterborough, ON, Canada*

[5] *Department of Mechanical Engineering, McMaster University, Hamilton, ON, Canada*

[6] *Joint Department of Medical Imaging, University Health Network, Toronto, ON, Canada*

[7] Royal Tyrrell Museum of Palaeontology, Drumheller, AB, Canada

[8] *Royal Ontario Museum, Toronto, M5S 2C6 ON, Canada*

[9] *Department of Radiology, McMaster University, Hamilton, ON, Canada*

* corresponding author: seper.ekhtiari@gmail.com

Introduction Osteosarcoma is one of the most devastating diseases in orthopaedic oncology, most commonly affecting young patients in their second decade of life. It has been hypothesized that given its osteoblastic nature and timing, there may be a relationship between osteosarcoma development and growth velocity. Osteosarcoma has also been previously described in extant animals such as birds, reptiles, crocodiles, and amphibians. To date, however, no bony malignancies have been reported in dinosaurs. Here we describe a radiographically and histologically diagnosed case of osteosarcoma in a pathological fibula from a horned dinosaur (Centrosaurus apertus). The diagnosis was confirmed through direct comparison with a confirmed case of human osteosarcoma in a fibula**.**

Method and materials The specimen consists of the distal half of an adult Centrosaurus apertus fibula collected from a bonebed in the Dinosaur Park Formation, Alberta, Canada (Campanian). With ethics approval, the specimen was compared to a specimen of a proximal human fibula with a confirmed osteosarcoma. Both specimens underwent micro computed tomography (micro-CT) as well as microscopic histological examination by a pathologist and radiologist specializing in musculoskeletal oncology.

Results and discussion Gross examination of the dinosaur specimen reveals a tumour that takes up the proximal half of the specimen, located about 150mm from the normal, distal end of the bone. The mass measures 155mmx92mmx61mm. The compact bone covering the tumour is quite thin in some places, suggestive of neocortex formation. In addition, unusual foramina consistent with malignant angiogenesis are clearly visible. The High Resolution X-Ray Computed Tomography (HRXCT) scan of the dinosaur specimen reveals a Codman triangle and proximo-distal invasion of the tumour throughout the cortex. The histological examination demonstrated a lack of zonation with bone maturation that would be seen if the lesion were a fracture callus, and evidence that the tumour extends throughout the cortex of the bone (confirmed on histological and radiological examination). Furthermore, the bone formation is irregular and inconsistent with Wolff's Law. In addition, there was evidence of extensive and multifocal penetration and destruction of the cortex by architecturally abnormal neoplastic bone with islands of normal bone visible. These findings were consistent with the proximal human fibula specimen from a patient with a confirmed diagnosis of osteosarcoma, which revealed similar findings on magnetic resonance imaging (MRI), micro-CT, and histology.

Conclusions and future work The gross, radiographic, and histologic appearance of the dinosaur fibula were identical to the human osteosarcoma, despite the lack of preserved soft tissue structures in the former. We conclude with a similar degree of certitude as would be possible in a patient in clinical practice, that this dinosaur bone demonstrates an osteosarcoma and thus represents the first histologically confirmed case of cancer in a dinosaur. Our findings confirm that dinosaurs suffered from primary bone cancer, and suggest that the exceptionally fast-growing bones of dinosaurs may be particularly prone to the development of osteosarcoma - in the same manner that this tumour commonly occurs in humans.

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List of 2020 Participants

United Kingdom

Dr Mele, Elisa, University of Loughborough
Dr Mieczakowski, Anna, University of Cambridge
Prof Tankasala, Harika, University of Coventry

Canada

Aranguren van Egmond, Derek, University of Toronto
Deering, Josep, McMaster University
deVet, Taylor, McMaster University
Ekhtiari MD, Seper, McMaster University
Gonder, Nicole Sarah, McMaster University
Rier, Elyse, McMaster University
Tyedmers Walker, Adam, McMaster University
Prof Wohl, Gregory, McMaster University
Prof Yu, Bosco, McMaster University

China

Yang MD, Liang, Dalian Medical University
Zheng MD, Kai, Zhengzhou University, Dalian Medical University

United States

Emun, Yoel, University of Alabama

Poland

Prof Dlotko, Pawel, Polish Academiy of Science

Italy

Prof Bagherifard, Sara, Politecnico di Milano
Prof Guagliano, Mario, Politecnico di Milano
Mora Sierra, Daniel Camilo, Politecnico di Milano

Switzerland

Abel MD, Frederik, University Hospital Zurich

Germany Non-Giessen

Bosbach, Konstantin E, University of Freiburg

Dr Schwarz, Oliver, Fraunhofer IPA, Stuttgart

Senge, Jan Felix, University of Bremen

Germany Giessen

Biehl MD, Christoph, Justus-Liebig University of Giessen

Dr Bosbach, Wolfram A, Justus-Liebig University of Giessen

Ebeling, Michèle, Justus-Liebig University of Giessen

Prof Heiss MD, Christian, Justus-Liebig University of Giessen

Kampschulte MD, Marian, Justus-Liebig University of Giessen

Giessen University Medical Faculty

29, Klinikstrasse

Giessen 35390

Germany

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